AUTOCOLLIMATOR MANUAL

MODEL MRA-150

SERIAL NO. 201

CUSTOMER ____________________

____

DATE ____________________

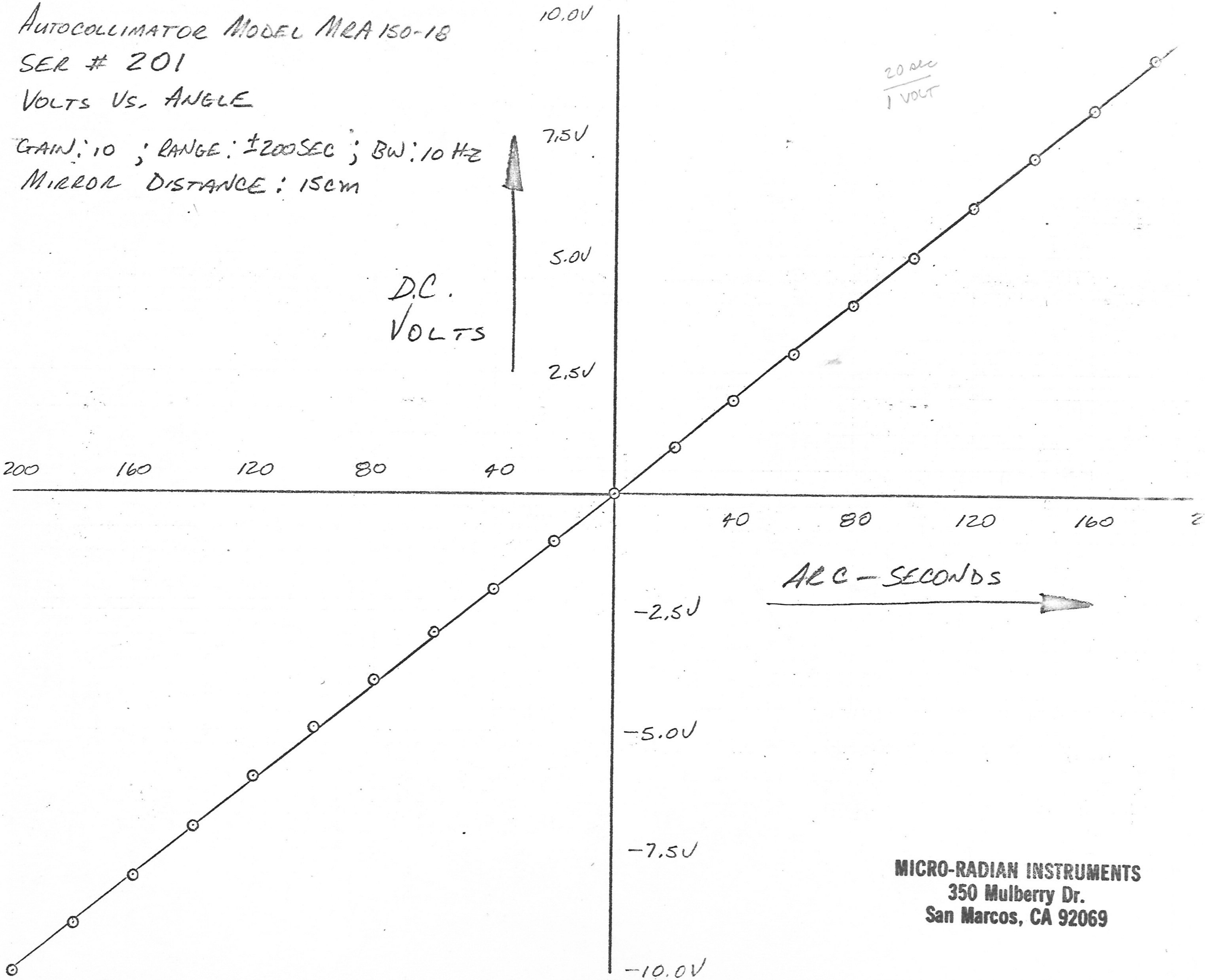
MICRO-RADIAN INSTRUMENTS
350 MULBERRY DRIVE
SAN MARCOS, CALIF. 92069

(714) 744-4133
TELEX·181799

TABLE OF CONTENTS BY SECTION NUMBER

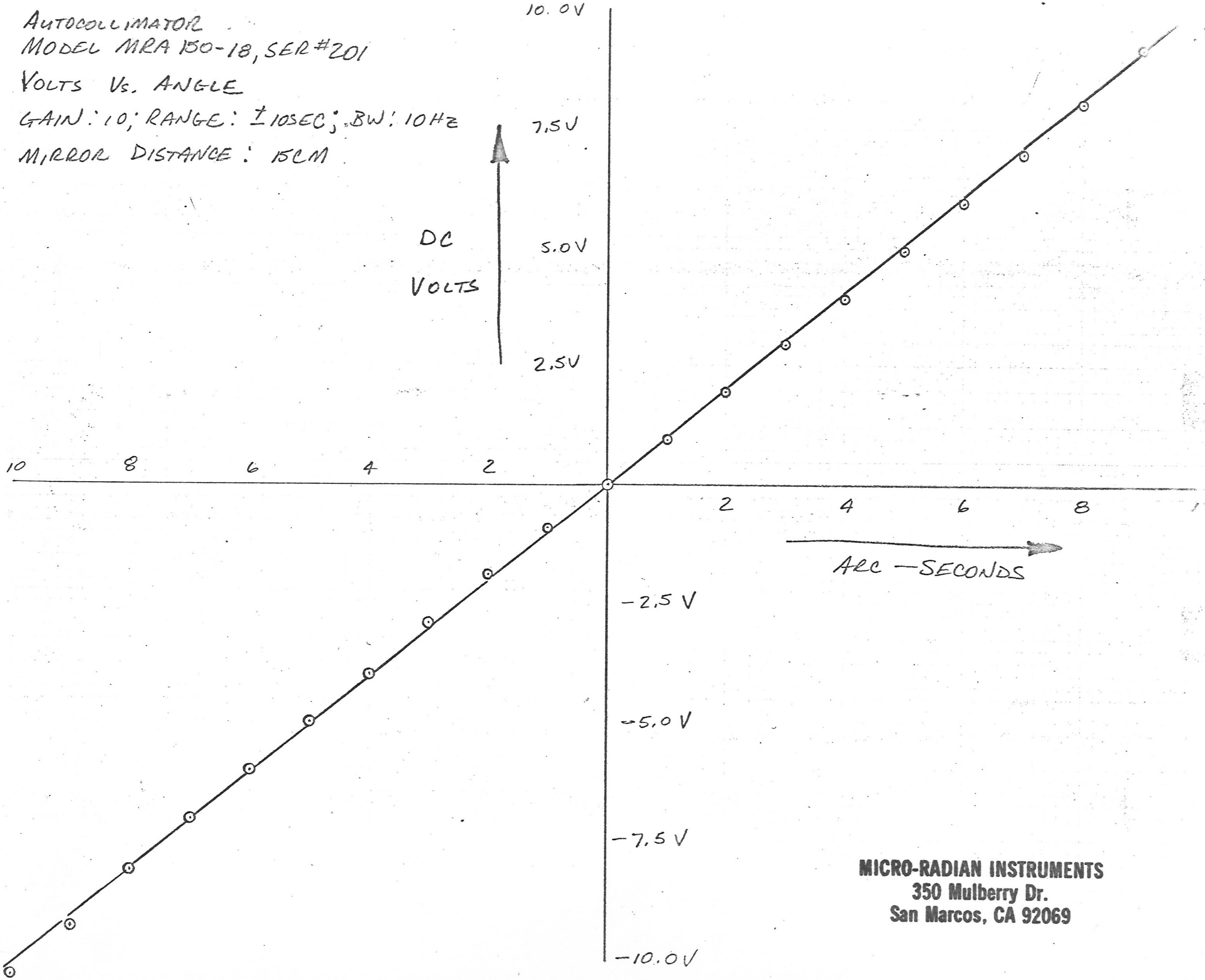
AUTOCOLLIMATOR MODEL MRA 150-18
SER # 201
VOLTS VS. ANGLE

GAIN: 10 ; RANGE: ±200 SEC ; BW: 10 Hz
MIRROR DISTANCE: 15cm



MICRO-RADIAN INSTRUMENTS
350 Mulberry Dr.
San Marcos, CA 92069

AUTOCOLLIMATOR
MODEL MRA 150-18, SER #201
VOLTS VS. ANGLE
GAIN: 10; RANGE: ± 10SEC; BW: 10Hz
MIRROR DISTANCE: 15CM



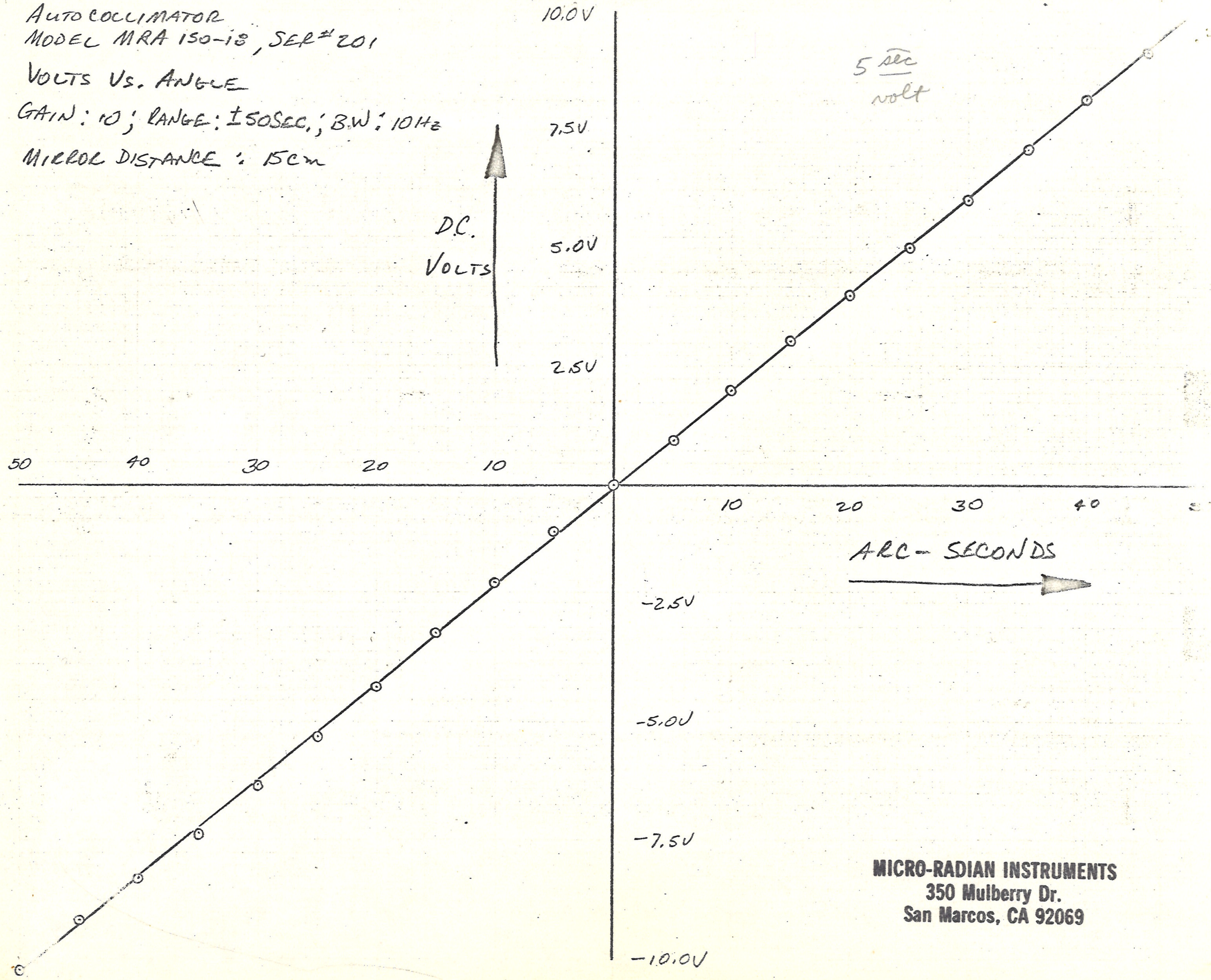
MICRO-RADIAN INSTRUMENTS
350 Mulberry Dr.
San Marcos, CA 92069

AUTOCOLLIMATOR
MODEL MRA 150-18, SER# 201

VOLTS VS. ANGLE

GAIN: 10; RANGE: ±50SEC.; B.W.: 10Hz

MIRROR DISTANCE: 15cm



MICRO-RADIAN INSTRUMENTS
350 Mulberry Dr.
San Marcos, CA 92069

1.0 Introduction

1.1 The Micro-Radian autocollimator is an electro-optical instrument that uses its own collimated light to accurately measure small angular displacements of an external reflector.

1.1.1 The autocollimator functions by projecting its beam of light onto the reflector and measuring changes in the direction of the reflection.

1.1.2 Although the reflector is essential to the operation, it is not supplied except as an accessory. Usually the reflector is an integral part of the equipment that is subject to rotational, torsional or flexural movement.

1.1.3 The autocollimator does not constrain nor interact with the equipment bearing the reflector, and in this respect it differs from electromagnetic or electrostatic pick-offs.

2.0 Components

2.1 The autocollimator consists of an optical head and an electronic unit.

2.1.1 The optical head contains the optical elements, the light sources, a photodetector, a preamplifier, and an aiming mechanism.

2.1.2 The electronic unit contains regulated power supplies, a lamp driving circuit, a demodulator-phase detector circuit, a gain control and a digital panel meter. The meter displays the analog output voltage.

2.1.2.1 A BNC connector on the front panel supplies an analog output for interfacing the autocollimator with computers, recorders and oscilloscopes.

3.0 Configuration, Dimensions

3.1 The Micro-Radian optical head is compact, rigid, and stable, with a cylindrical shape, and a one-inch aperture (See Fig. 1). The low internal heat dissipation results in a low warm-up drift, and symmetry provides the ability to follow ambient temperature changes with very little thermal distortion.

3.1.1 The optical head may be mounted in any position.

3.2 The electronic unit is supplied in a cabinet with optional rack-mount side pieces. The cabinet for a single axis instrument measures:

inches: 12 wide, 10.3 deep, 3.5 high

cm: 30.5 wide, 26 deep, 9 high

The cabinet for a dual-axis instrument measures:

inches: 16.8 wide, 12 deep, 5.1 high

cm: 43 wide, 30 deep, 13 high

4.0 Solid State

4.1 All active devices in both the optical head and the electronic unit are solid state.

4.1.1 The 2 light sources are light-emitting diodes, modulated 180 degrees out of phase. Their probable life is several decades.

4.1.1.1 The light does not harm the eyes when looking into the barrel.

5.0 Resolution

5.1 The ability of an autocollimator to resolve small angular changes is not directly related to the size of the aperture. The light returning from the reflector and re-entering the autocollimator forms an image in the vicinity of a slit, behind which is a photo-sensitive detector. Rotation of the reflector causes the return image to move across the slit and changes the amount of light falling on the detector. Therefore, image movement, not image sharpness, is what is being resolved. The detector is so sensitive that an objective lens focal length of only a few inches provides sufficient image movement for resolving less than a tenth of a second of arc (0.5 microradian). Even when looking at a mirror 1/4 inch in diameter, the resolution remains better than one second (5 microradians).

5.1.1 In astronomy, by way of distinction, resolution refers to the ability of a telescope to separate star images, and is therefore a function of the aperture size.

6.0 Measuring Axis

6.1 This autocollimator will measure angular changes about any one axis, and is known as a single axis autocollimator.

6.2 By rotating the optical head in the clamp that holds the barrel, the measuring axis may be chosen to be vertical, horizontal, or at any angle in between.

6.3 It is often customary to speak of the measuring direction instead of the measuring axis, as by saying that the instrument is set up for azimuth measurements, or elevation measurements.

6.3.1 The measuring direction may be identified by looking into the barrel when the instrument is turned on. The measuring direction is at right angles to the slit.

7.0 Mounting

7.1 The optical head is intended to be mounted by clamping the barrel in a stand, fixture, or V-block (See 3.1.1). Circumferential clamping is preferable to V-block clamping.

7.1.1 Warning: Do not clamp too tightly. There is a sliding cell inside the barrel, and even though the barrel wall is 1/4 inch thick hardened steel, it can be forced out of round enough to jam the cell, especially in a V-block. If the knurled knob slips and does not drive the dial (other than at the end of travel), ease up on the clamp. However, slippage of the knob does not cause slippage of the dial reading (See 8.1.1).

7.1.2 Micro-Radian autocollimator stands are available that exert a sufficient but limited circumferential clamping force. The stands come in two styles: fixed; or kinematically adjustable in 2 axes, with coarse and fine adjustments.

8.0 The Knob, Drum Dial, and Linear Scale on the optical head.

8.1 The large knob at the rear of the optical head turns the drum dial and also operates a micrometer screw that changes the aiming direction of the light beam (see 9.0).

8.1.1 The knob is a two-part device. The knurled section drives the micrometer screw through a clutch.

8.1.1.1 The larger, shorter, forward section of the knob drives the micrometer screw directly, and is only to be used for backing off if the micrometer screw has been driven into the stops at either end of its travel.

8.2 One turn of the drum dial changes the aiming direction by 5 seconds of arc (approx. 25 microradians).

8.2.1 The dial is graduated in tenths of a second (approx. 0.5 microradian).

8.2.1.1 Note: 0.5 microradian is 3% larger than 0.1 sec. See 30.0.

8.3 The linear scale pointer follows the micrometer screw.

8.3.1 Each graduation on the linear scale corresponds to one turn of the dial, so the dial and scale are read just like a micrometer.

8.4 The dial/scale measuring range covers 200 seconds (approx. 1 milliradian), and requires 40 turns of the dial.

8.5 The dial is used for direct measurements (see 14.1), for calibrating the analog output and the error signals (see 14.2 and 14.3), and for fine alignment.

8.6 Autocollimators without dials are made by Micro-Radian for analog and error applications. When used for analog readout, such an instrument is sometimes called an angle transducer. The same instrument used as an error detector might be called a signal autocollimator or a nulling autocollimator. The size can be reduced to 23 x 33 x 38 mm (0.9 x 1.3 x 1.5 inches).

9.0 Principles of Operation

9.1 The optical schematic of the autocollimator is shown in Fig. 2.

9.1.1 In Fig. 2a, M is the external mirror, L is the objective lens, W is an optical wedge, S_1 and S_2 are light sources, and R_1 and R_2 are reflecting surfaces. R_1 and R_2 are separated by a small gap or slit which admits return light to the photodetector D.

9.1.2 The wedge W is moveable to the left and right by means of the knob and lead screw. In Fig. 2a, W is shown in its center position.

9.1.3 S_1 and S_2 are modulated out of phase. S_1 lights on the positive alternations of the a.c. power, and S_2 lights on the negative alternations.

9.1.4 The direction of mirror rotation is sensed according to the phase of the light reaching D.

9.2 If M is rotated as in Fig. 2b, the same emergent ray as in Fig. 2a now returns too high. By moving the wedge toward the lens (Fig. 2c), the emergent ray is made to fall perpendicularly on M and return on itself.

9.3 If M is rotated as in Fig. 2d, the same emergent ray as in Fig. 2a now returns too low. In this case, moving the wedge toward the slit (Fig. 2e) causes the emergent ray to fall perpendicularly on M and return on itself.

9.4 The relation between mirror rotation and wedge travel is inherently linear. Therefore, the dial and scale have uniform graduations without any need for a cam, sine bar, or other correcting mechanism.

9.5 The dial/scale readings are independent of the mirror distance because the light is collimated.

10.0 Variable Aim

10.1 The term "variable aim" has been adopted to describe the fact that the Micro-Radian autocollimator aligns by varying its aiming direction in order to look perpendicularly at the mirror, as in Figs. 2a, 2c, and 2e. This patented feature is unique.

11.0 Alignment

11.1 When conditions are as shown in Figs. 2a, 2c, and 2e, the autocollimator is said to be aligned, or nulled, on the mirror.

11.1.1 Alignment corresponds to a zero readout on the digital display.

11.1.2 Alignment corresponds to the zero cross-over point on the analog output.

11.2 Alignment also requires that the reflection be approximately centered in the non-measuring direction (often called the orthogonal direction).

11.2.1 The best procedure for centering the return image in the non-measuring direction is to rotate the autocollimator 90° in its stand and adjust for an approximate null, then rotate back to the measuring position.

12.0 Cross-Coupling

12.1 When mirror rotation in the orthogonal direction causes a readout in the measuring direction, cross-coupling is said to be present. It occurs when the return image is moving slightly slantwise with respect to the slit. It is a problem that may be encountered in setting up any autocollimator.

12.1.1 By successive small rotations of the autocollimator barrel in its mount, an orientation will be found where the cross-coupling is minimized. The minimum will usually be less than 1%.

13.0 Starting Point for Measurements

13.1 Any arbitrary initial alignment, as in Figs. 2a, 2c, or 2e, may be used as the starting point for measurements.

13.2 The dial is convenient for the last seconds of adjustment needed to establish alignment; much easier than trying to budge the autocollimator stand or the mirror stand.

14.0 Three Usages for the Autocollimator: Dial Measurements, Analog Measurement (Tracking), and Error Signals.

14.1 Dial Measurements: If the mirror rotates after an initial alignment has been established, the amount of rotation may be accurately measured by using the dial to re-establish null and taking the difference between the initial and final dial readings. Going from null to null is the most accurate way to use an electronic autocollimator because the full accuracy of the lead screw is obtained.

14.1.1 Even though an anti-backlash feature is built in, it is possible that backlash may amount to one or two tenths of a second. Approach null from the same direction when readings are to be made to 0.1 second.

14.2 Analog Measurements and Tracking: Mirror rotation may be closely measured by meter readings and/or analog output. Analog tracking is used for convenience or whenever the mirror rotation is too rapid or too prolonged for follow-up with the dial. The analog output may be recorded (See 2.1.2.1). The calibration is easily determined as in 16.0; accuracy is discussed in 17.0.

14.2.1 The analog output is a DC voltage. Its value drops to zero at null, and its polarity reverses after crossing through null. Saturation levels are approximately ±10 volts.

14.3 Error Signals: The autocollimator may be used as the error signal generator in angle-holding, or null-seeking, closed-loop servo systems. The error signal is essentially the analog output, with the distinction that the servo is concerned with the slope of the output while analog measurements relate to the magnitude of the output.

14.3.1 Calibration of the error signal usually amounts to taking one point (see 15.3).

15.0 Gain, Scale Factor and Slope.

15.1 The gain control is located on the panel of the electronic unit.

15.2 The scale factor (the volts/second) of the analog (or error) signal is adjustable by means of the gain. For example, after a null has been established, if the dial is turned 50 seconds and the gain is adjusted to bring the analog output to 10 volts, you have a ±50 second analog readout (see also 24.5).

15.3 The slope established by a one-point calibration, as easily as the example in 15.2, is usually adequate for servos.

16.0 Calibration

16.1 Calibrating the analog means making a plot of output voltage vs seconds, and is readily done for a particular set-up by turning the dial in increments and noting the output voltage, or the meter reading, for each dial setting. A plot of this type is included in this manual. The analog calibration is based on the fact that turning the dial through a given number of seconds while looking at a fixed mirror is exactly equivalent to turning the mirror through the same number of seconds while the dial is fixed. The more points on the calibration plot, the greater the accuracy, but after the shape of the voltage-angle relationship has been determined once, fewer points should suffice for new set-ups. An appreciable change in mirror distance, mirror size, or gain constitutes a new set-up.

17.0 Accuracy and Linearity

17.1 Dial: 0.1 second over any 5 seconds,
1.0 second over any 100 seconds.

17.1.1 The dial calibration is traceable to the U.S. Bureau of Standards.

17.1.2 Autocollimators of an exactly similar mechanical design and construction date back to 1968, and there have been no known errors in dial calibration, nor any requests for correction on even the oldest instruments.

17.2 Analog Linearity: normally ± 0.2 sec over $\pm$ 10 sec at full gain.

At lower gain, to cover a wider analog range, it is advisable to obtain a calibration curve as in 16.0. Linearity can be adjusted to be best at one particular gain, usually chosen to be full gain.

17.2.1 Analog Accuracy: as good as the calibration (see 16.0).

17.3 Error Signals: null repeatability = ±0.1 sec or less. For slope accuracy in servo nulling, see 15.3.

18.0 Dynamic Response

18.1 The data bandwidth, or the maximum frequency at which the analog output voltage will track an oscillating mirror, is, by Nyquist's criterion, equal to 0.5f, where f is the frequency at which the light sources are modulated. However, Micro-Radian sets the bandwidth equal to 0.1f.

18.2 On older instruments, f was the power line frequency, unless a bandwidth higher than 5 or 6 Hz was ordered. Beginning with Serial No. 225, all electronic units contain oscillators to drive the light sources at approximately 400 Hz, unless a higher bandwidth is ordered. Therefore, the standard bandwidth is 40 Hz.

18.2.1 The digital panel meter samples the analog output at a 3 Hz rate. Details of higher bandwidths are available at the BNC output connector.

18.2.2 The oscillator is powered by regulated D.C., which gives improved stability. A.C. line voltage fluctuations cannot influence the autocollimator read-out nearly as much as formerly, when the light sources operated from a transformer on the line.

18.2.3 Bandwidths to 1000 Hz may be ordered.

19.0 Acquire

19.1 When a reflection falls on the detector and causes a reading on the digital display, the autocollimator is said to have acquired the reflection.

19.2 For seeking a reflection, the light sources are large enough so that the acquire range extends over ±15 minutes of arc. (± 900 sec)

19.3 Acquire indication is a standard feature on all Micro-Radian electronic autocollimators. The digital display will only light up when the autocollimator has acquired its own light.

20.0 Noise

20.1 Noise, as seen on the meter and on the output, originates both internally and externally.

20.1.1 Separation of noises: External noise may be distinguished from internal noise by covering the objective lens with a dull black mask and noting the decrease, if any, in the meter/output fluctuations. The remaining noise is internal.

20.1.2 Internal noise has three sources:

20.1.2.1 Photodetector and circuit noise.

20.1.2.2 Refractive variations due to air convection in the internal light path (almost non-existent inside the small Micro-Radian barrel).

20.1.2.3 Ripple from the demodulator, at twice the modulation frequency, amounting to a few millivolts.

20.1.3 External noise has three sources:

20.1.3.1 Refraction due to air temperature variations in the optical path between the autocollimator and the mirror. This can easily cause fluctuations of a second in a few inches of path, and several seconds in a path of several feet, especially if there are drafts, or air currents from heaters or air conditioners.

20.1.3.2 Vibration: Even though the autocollimator and the mirror might be clamped to a heavy base, the whole structure will seldom vibrate as a unit without flexure. Vibration may come from machinery in the next room or from traffic. Place a dish of water on the base and look at the reflection of a ceiling light in the surface. Ripples signify a problem.

20.1.3.3 Pick-up from 60 Hz wiring, fluorescent fixtures, and equipment; not normally encountered unless fluorescent light enters nearly along the axis. Avoid shiny metal parts adjacent to the mirror.

20.2 Remedies: Air noise and vibration noise contain low frequencies that may fall within the signal bandwidth. To that extent they cannot be filtered out, but must be avoided.

20.2.1 Air turbulence may be diminished by enclosing the optical path in a cardboard tube. Of course, there may be convection within the tube, so elevation measurements may be accompanied by more air noise than azimuth measurements.

20.2.2 The remedy for vibration is isolation.

20.3 Noise limitation: The unavoidable noise puts a limitation on the minimum readable angular change (see 21.1.1). As with any signal containing noise, the limit is dependent on the allowable time for obtaining a mean reading.

20.3.1 Sometimes the user may wish to integrate, or smooth, the noise at the signal output, such as by adding an RC time constant to the output.

20.3.2 The signal plus noise may be recorded for a time, and a mean drawn through the noise.

21.0 Trade-Offs

21.1 The most important trade-off is sensitivity vs bandwidth. As bandwidth increases toward 1000 Hz, more of the internal noise spectrum rides through, and sub-second signals get buried. On the other hand, if bandwidth is filtered down to the order of 0.1 Hz, the sensitivity approaches 0.001 sec.

21.1.1 Sensitivity is defined here as the minimum detectable signal and is set equal to the RMS noise voltage.

21.1.2 Bandwidth is defined as the frequency at which the low-pass characteristic of a 3rd-order Chebyshev filter is down 3db. The ripple factor of the filter is 0.1.

21.1.3 The following table gives reasonable expectations:

Bandwidth	RMS Noise-equivalent angle Micro-radians	Seconds
0.1 Hz or less	0.005	0.001
1.0 Hz	0.05	0.01
5	0.1	0.02
40	0.5	0.1
100	1.2	0.25
200	2.5	0.5
500	3.7	0.75
1000	5	1.0

21.2 Another Trade-Off is Mirror Distance vs Analog Range. The following table summarizes the calculated relationship as modified by practical experience:

Max. Total Analog Range Milliradians	Seconds	Corresponding Max. Mirror Distance Meters	Feet
6.0	1200 (±600)	1.3	4
3.0	600	2.8	9
2.0	400	4.8	16
1.0	200	8.5	28
0.5	100	15	50
0.1	20	30	100

22.0 Maximum Analog Signal

22.1 The Analog Signal is limited by either electronic saturation (±10V) (See 14.2.1), or by the slit becoming full of reflected light (in which case further rotation of the mirror cannot put more light on the photo-detector). The latter condition is called geometrical saturation.

22.2 The standard slit saturates for changes in the direction of the reflection of about ±150 sec (0.75 millirad). Wider slits, saturating at various ranges up to ±600 sec (±3 mr), are optional, but that seems to be the widest for which the output can be reasonably linearized.

23.0 Temperature and Humidity

23.1 Operating temperature: Maximum 52C/125F
Minimum -18C/0F or the dew point, whichever is higher.

23.2 Storage temperature: Maximum 65C/150F
Minimum -30C/-20F or the dew point, whichever is higher.

23.3 Humidity: The relative humidity is not important provided condensation does not occur. The optical elements cannot function properly if coated with moisture droplets, frost, or ice. If a drop of condensation is collected between some of the optical elements and then frozen, the force exerted could cause a permanent displacement that might impair operation.

23.4 Temperature Coefficient: The null may shift a maximum of 0.1 arc second per degree C in the range from 15C/60F to 32C/90F. Beyond these temperatures, the coefficient has not been measured.

24.0 Operation

24.1 Mount the optical head (see 2.1.2, 6.2, and 7.0).

24.2 Plug the interconnecting cable between the optical head and the electronic unit.

24.3 Plug the power cable into a 3-wire outlet of the proper voltage and frequency.

24.4 Turn on the power switch and see that the pilot light is lit. The autocollimator will be operational immediately, but allow 5 minutes for warm-up. Suggested reading during this time would be sections 4.1.1.1, 8.0, 9.0, 11.0, 12.0, 13.0, 14.0 and 15.0. A few other sections of this manual are worth a glance, too.

24.5 Gain Control: Start with the gain low while acquiring a reflection, unless the mirror is out 20 feet or so. As the alignment gets better, the gain can be increased. The final gain setting will depend on what analog working range you want, such as ±10 seconds, ±25 seconds, ±50 seconds or some other range. See 15.2, 21.2 and 22.0.

25.0 Digital Display

25.1 The standard digital panel meter is a 3 1/2 digit solid state voltmeter which samples and displays the analog output voltage at a 3 Hz rate.

25.2 See also 2.1.2, 11.1.1, and 18.2.1.

26.0 Dark Balance

26.1 With the autocollimator turned on, cover the objective lens with any black, non-reflecting material so that none of the instrument's own light or any stray outside light, will be reflected into the barrel. The digital display should read zero. If it does not, loosen the lock nut on the "Dark Bal" pot on the front panel, and carefully adjust until the meter does read zero. Tighten the lock nut and uncover the objective lens.

27.0 Output Connector

27.1 A BNC connector on the front panel supplies an analog output for interfacing the autocollimator with oscilloscopes, computers and recorders.

27.2 Short circuiting the output to ground will do no harm to the electronics.

27.3 The output will source or sink 5 milliamps.

28.0 Mirrors and Prisms

28.1 Mirrors for use in making measurements to 0.1 sec should be of the front-surface type, and be flat to about 1/10 wave. The best material is fused quartz, but pyrex is satisfactory in a laboratory environment. The thickness should be 15 to 20% of the diameter so that the mounting clamps will not cause appreciable bending.

28.2 Prisms such as pentas and porros must be free of strains and striae, and have deviational errors of no more than a few seconds.

28.3 Mirrors and prisms of autocollimator quality can be supplied.

29.0 Stands for mirrors, prisms, and autocollimators, either fixed or kinematically adjustable in 2 axes, are made by Micro-Radian. The adjustable stands employ differential screws with coarse and fine adjustments. Special stands for a dual-axis pair of optical heads are also available.

30.0 Radians vs Degrees

1 radian = $\frac{360}{2\pi}$	=	57.29578 degrees
1 milliradian	=	0.05729578 degrees
	=	3.4377468 minutes
	=	206.2648 seconds
1 microradian	=	0.2062648 seconds
1 degree	=	0.01745329 radians
	=	17.45329 milliradians
1 minute	=	0.00029088 radians
	=	0.29088 milliradians
	=	290.88 microradians
1 second	=	0.0000048481 radians
	=	0.0048481 milliradians
	=	4.8481 microradians

ALL SOLID STATE ELECTRONIC AUTOCOLLIMATOR

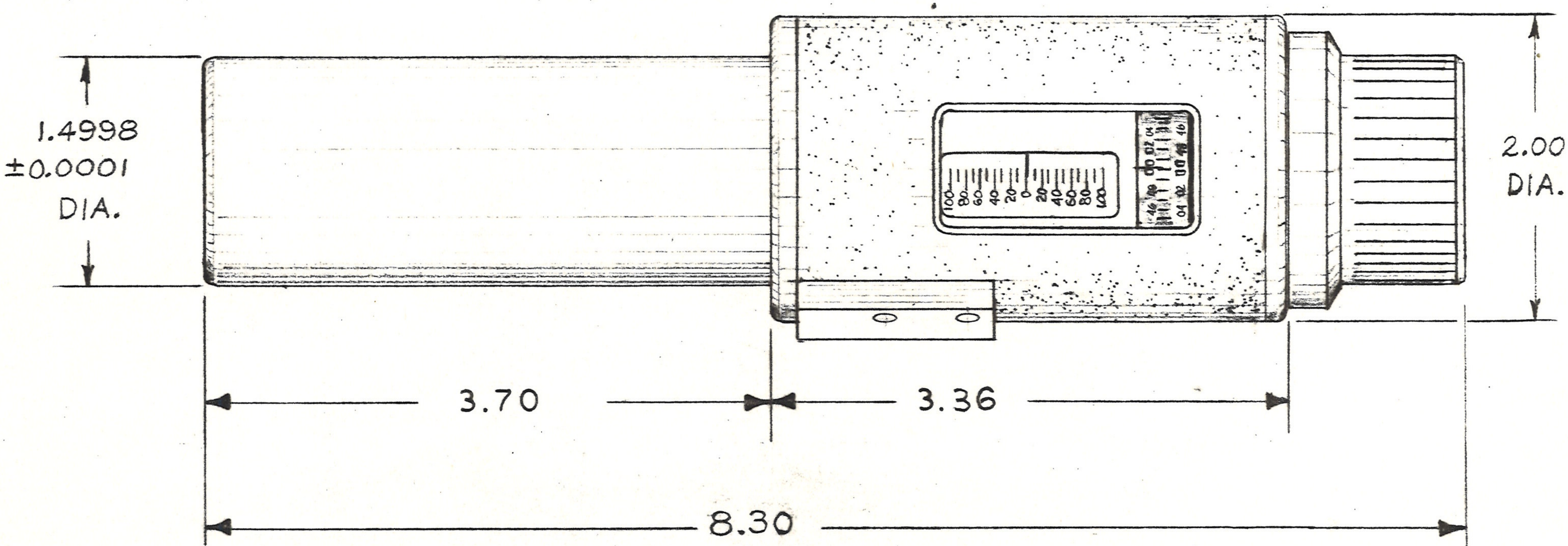
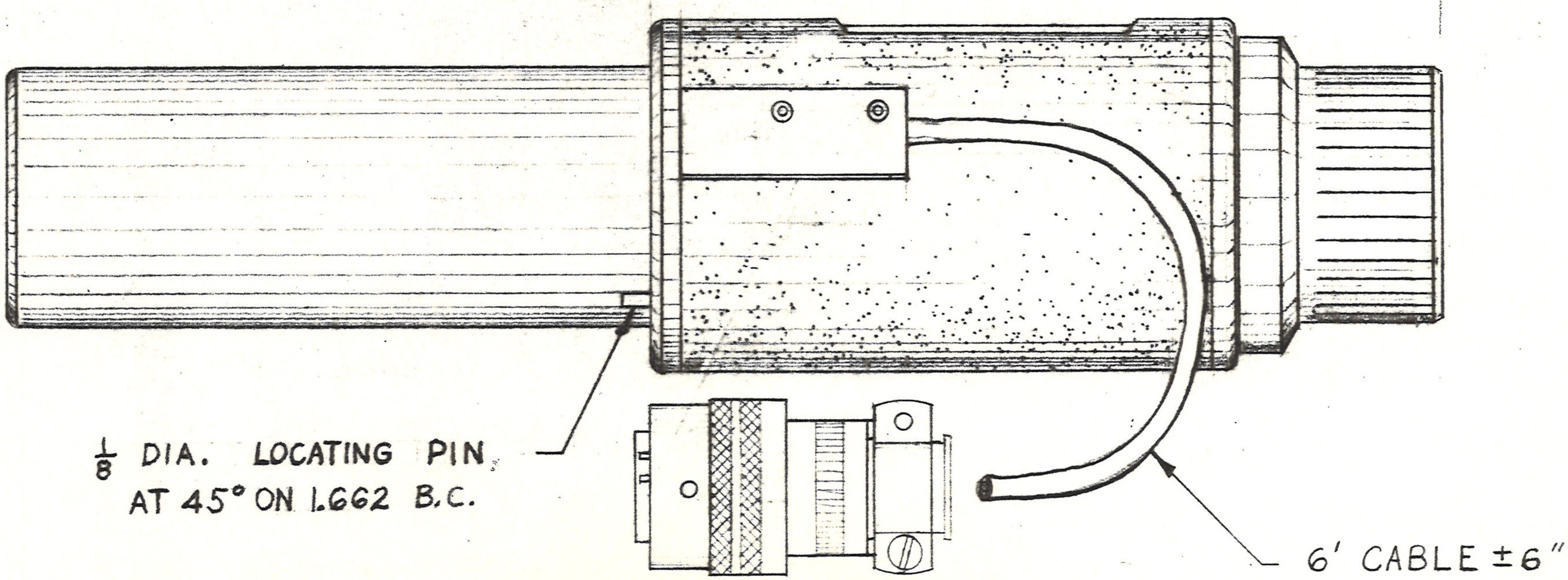
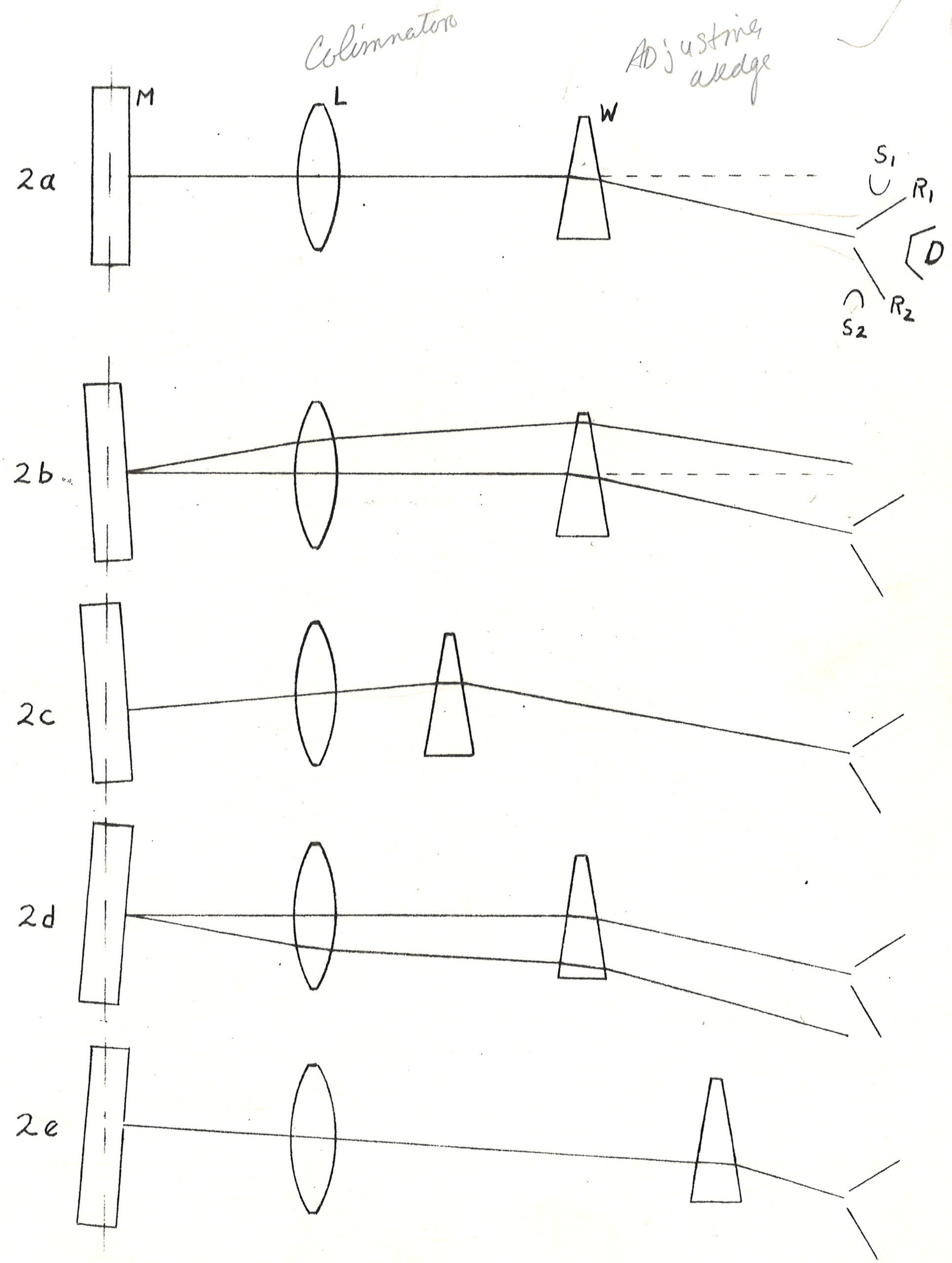


FIGURE 1



MICRO-RADIAN INSTRUMENTS 350 MULBERRY DR. SAN MARCOS, CALIFORNIA 92069

Figure 2 Optical Schematic



micro-radian®
Micro-Radian Instruments, Inc., 350 Mulberry Drive, San Marcos, California 92069 • 714/744-4133

OPERATING INSTRUCTIONS

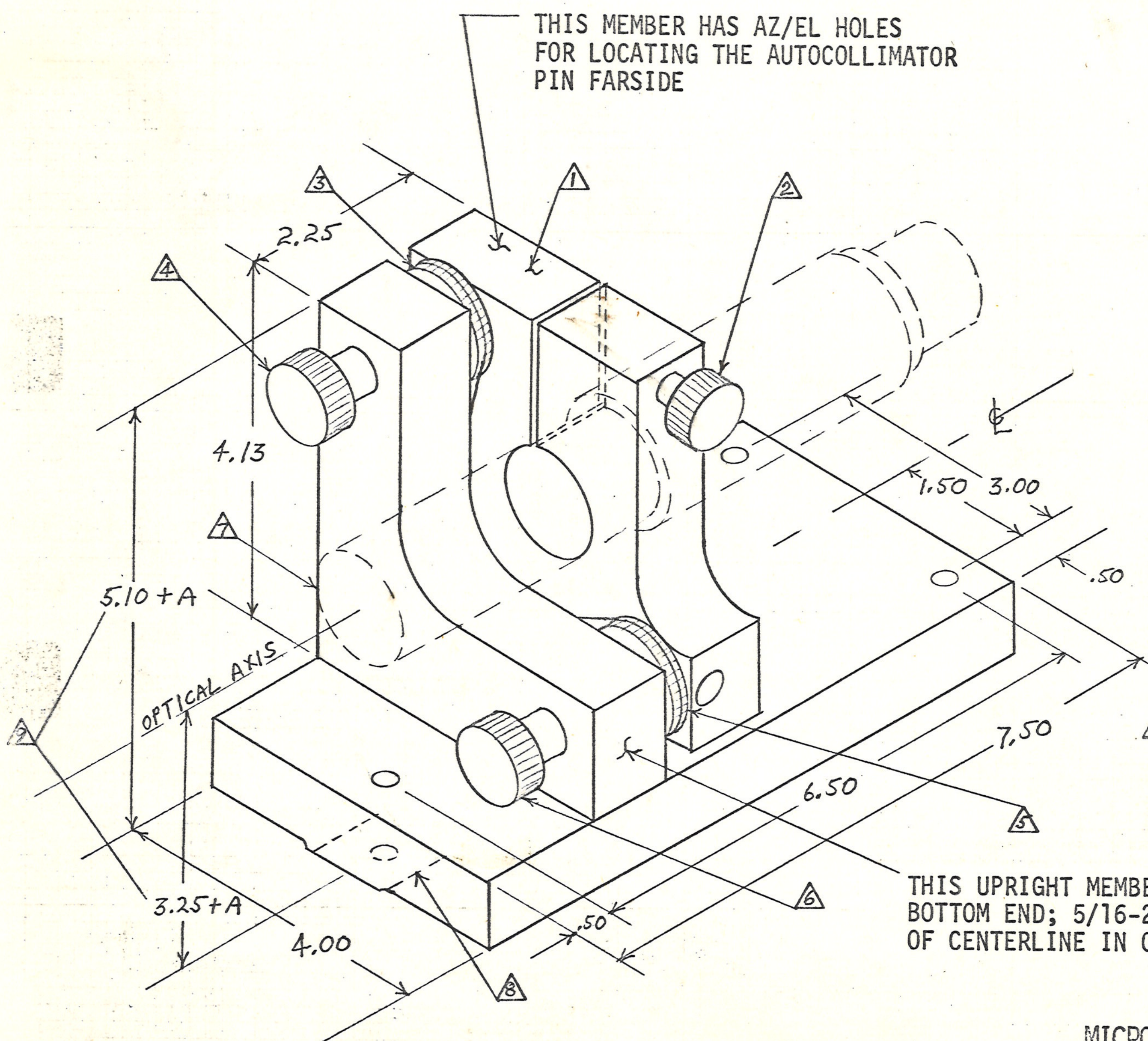
MRA-150 Autocollimator with MRS-20 Stand

SET-UP

Open the circumferential clamp on the stand by tightening the clamp knob. Insert the optical head, sliding it forward until the index pin mates with one of the two index holes in the clamp. Indexing the autocollimator so that the scale window is up places the optical head in position to measure azimuth angles. Rotating the optical head 90° to the second index position sets the instrument for elevation angles (scale window facing sideways). Plug the interconnecting cable from the optical head into the electronic unit. Aim the optical head at the mirror.

INITIAL ALIGNMENT

Turn the electronic unit on and set the gain control at position 2. The power switch and meter should be illuminated and a full circle of red light should be seen when looking into the barrel of the optical head. This red light is harmless to the eye. If you will be measuring azimuth angles, turn the optical head in the stand first to the "elevation" position (window sideways) and adjust the autocollimator stand (or the mirror, if it is adjustable) in elevation with the upper knob until a signal is acquired and the needle of the panel meter pegs to one side. You may have to move the mirror or autocollimator manually in the azimuth direction while making this elevation adjustment. Continue with small elevation adjustments until you notice the needle of the panel meter swing from one side to the other (not just from one side to the center). Reverse the adjustment just made until the panel meter reads approximately in the center of its scale. At this point the system is aligned in elevation. Return the optical head to the "azimuth" position (window up) and adjust the optical head, or the mirror, in azimuth until the needle of the panel meter again swings from one side to the other. Back up carefully on this last adjustment until the needle is near the center of the scale. Turn the knob on the optical head until the needle reads center scale and turn the gain up.



1. KINEMATICALLY MOUNTED AUTOCOLLIMATOR CLAMP
2. CLAMP RELEASE
3. ELEVATION COARSE ADJ THUMBWHEEL
4. ELEVATION FINE ADJ
5. AZIMUTH COARSE ADJ THUMBWHEEL
6. AZIMUTH FINE ADJ
7. FRONT OF BARREL APPROX. FLUSH WITH FRONT OF STAND
8. .250 DIA HOLE THRU 1 INCH SQ PAD TYP 3 PLACES. PAD LAPPED
9. "A" DIM ON SPECIAL ORDER
10. EDGES CHAMFERED

MICRO-RADIAN INSTRUMENTS
350 MULBERRY DRIVE
SAN MARCOS, CALIF. 92069

MICRO-RADIAN INSTRUMENTS

WARRANTY

Micro-Radian Instruments warrants the following instrument:

Autocollimator, Model _________, Serial No. ________ to be free from defective parts or workmanship for a period of one year from ____________________, provided;

1. That the optical and electronic units are not dropped or abused.
2. That the optical head is not taken apart.
3. That the instrument is always connected to a power source of the proper voltage and frequency.
4. That the electronic unit is not probed with an ohmmeter.
5. That the optical elements are not allowed to get wet or frozen.
6. That transportation charges both ways are paid by the purchaser.
7. That examination of the defective instrument convinces us that the defect was our fault.

With the above reservations, all labor and materials to put the instrument in good working order will be provided at no charge during the warranty period.

Date ____________________ Signed ________________________

for Micro-Radian Instruments

MICRO-RADIAN INSTRUMENTS
350 Mulberry Drive
San Marcos, Calif. 92069
(714) 744-4133
TELEX 181799

MICRO-RADIAN INSTRUMENTS
350 MULBERRY DRIVE, SAN MARCOS, CALIF. 92069
(714) 744-4133
TELEX 181799

PRICE LIST

Effective Jan. 1, 1981

The prices below are tentative and subject to change without notice. Firm prices by Micro-Radian quote.

MRA-150	All-Solid-State Electronic Autocollimator, consisting of optical head, choice of cabinet or rackmount electronics, 2 meter interconnecting cable. Has digital display, sensitivity .1 arc second, 30 Hz bandwidth.	$ 5,660.00
Dual axis MRA-150	Has 2 optical heads with single chassis dual electronic unit, cabinet or rackmount.	$11,160.00
MRA-150	with .01 arc second sensitivity (noise equivalent angle less than .01 second, bandwidth 1 Hz max.)	$ 6,535.00
MRA-150	with .001 arc second sensitivity (noise equivalent angle less than .001 second, bandwidth .1 Hz max.)	$ 7,695.00
MRA-150	with front panel switches for selecting analog measuring ranges of ±10, ±50 and ±200 arc seconds as well as bandwidths of 1, 10 and 100 Hz.	$ 6,290.00
MRA-150	with front panel switch for selecting analog measuring ranges of ±10, ±50, ±200 and ±600 arc seconds.	$ 6,070.00
MRA-150	with front panel switch for selecting bandwidths of 1, 10, 100 and 1000 Hz.	$ 6,485.00
MRA-150	with front panel switches for selecting analog measuring ranges of ±10, ±50, ±200 and ±600 arc seconds as well as bandwidths of 1, 10, 100 and 1000 Hz.	$ 6,910.00
MRA-108	Nulling electronic autocollimator with digital display and analog output.	$ 4,595.00
MRS-20	2-Axis Kinematically Adjustable Autocollimator Stand.	$ 485.00
MRS-40	Adjustable Stand for side-by-side mounting of 2 MRA-150 optical heads.	$ 650.00

Interconnecting Cables to 25 feet with Bendix connectors both ends.
$135 + $4 per foot

Interconnecting Cables 26 to 60 feet require booster amplifier.
$395 + $4 per foot

Delivery: 30 to 60 days ARO depending on options ordered.

All shipment FOB San Marcos, California.